STUDY AND DESIGN THE INJECTION MOLD FOR SYNTHETIC BADMINTON FEATHER RIBS

NGHIÊN CỨU THIẾT KẾ KHUÔN ÉP PHUN CHO SẢN PHẨM SỐNG LÔNG NHÂN TẠO

Tran Quang Phuoc[1,2]
[1]Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology
[2]Vietnam National University Ho Chi Minh City

ABSTRACT

Nowadays, with the rapid advancement of industrialization, the livestock sector has become increasingly reliant on scientific and technological innovations in engineering practices. In the case of ducks, a reduced growth period may indeed impede feather development, which presents significant challenges for their utilization in technically demanding sectors. Notably, the manufacturing of badminton shuttlecocks, which traditionally relies on high-quality duck feathers, faces a potential material constraint issue. To address this pressing concern, this proposal advocates for the artificialization of the shuttlecock's feathers. This innovative solution aims to circumvent the material constraints posed by the changing livestock industry, while still ensuring the production of high-quality shuttlecocks. The study employed advanced simulation techniques, utilizing Moldflow software integrated with the finite element method and boundary element method, to identify potential defects and optimize the design. Following the simulations, process parameters were meticulously determined for the design and fabrication of the injection mold. The result was an efficient and effective method for producing artificial feather shuttlecocks, which maintains the quality standards of traditional models. This article presents a comprehensive analysis of the plastic injection-molded shuttlecock feather ribs product. It provides a detailed description of the engineering process, the challenges faced, the solutions developed, and the results of the rigorous testing process.

Keywords: *Micro Molding; Synthetic Badminton Shuttlecocks; Injection Molding.*

TÓM TẮT

Ngày nay, với sự phát triển nhanh chóng của công nghiệp hóa, ngành chăn nuôi ngày càng phụ thuộc vào những đổi mới khoa học và công nghệ trong thực tiễn kỹ thuật. Đối với vịt, thời gian sinh trưởng giảm có thể cản trở sự phát triển lông, điều này đặt ra những thách thức đáng kể cho việc sử dụng chúng trong các lĩnh vực đòi hỏi kỹ thuật cao. Đáng chú ý, việc sản xuất cầu lông, vốn dựa vào lông vịt chất lượng cao, đang phải đối mặt với vấn đề hạn chế về nguyên liệu tiềm ẩn.

Để giải quyết vấn đề cấp bách này, đề xuất này ủng hộ việc nhân tạo hóa lông cầu. Giải pháp sáng tạo này nhằm mục đích khắc phục những hạn chế về nguyên liệu do ngành chăn nuôi thay đổi, đồng thời vẫn đảm bảo sản xuất cầu lông chất lượng cao. Nghiên cứu đã sử dụng các kỹ ☞

thuật mô phỏng tiên tiến, sử dụng phần mềm Moldflow tích hợp với phương pháp phần tử hữu hạn và phương pháp phần tử biên, để xác định các khuyết tật tiềm ẩn và tối ưu hóa thiết kế. Sau khi mô phỏng, các thông số quy trình được xác định tỉ mỉ cho việc thiết kế và chế tạo khuôn ép phun. Kết quả là một phương pháp hiệu quả và hiệu quả để sản xuất cầu lông nhân tạo, duy trì tiêu chuẩn chất lượng của các mô hình truyền thống.

Bài viết trình bày phân tích toàn diện về sản phẩm gân lông cầu được ép phun nhựa. Nó cung cấp mô tả chi tiết về quy trình kỹ thuật, những thách thức phải đối mặt, các giải pháp được phát triển và kết quả của quy trình thử nghiệm nghiêm ngặt.

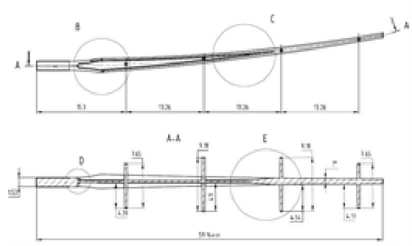
Từ khóa: *Ép phun vi mô; Cầu lông tổng hợp; Ép phun.*

1. INTRODUCTION

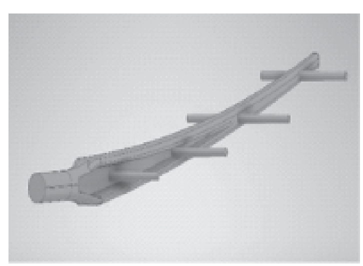
Plastic injection molding process is a popular and fast-growing manufacturing method that produces a wide range of products with complex shapes at low cost [1, 2]. The process involves injecting molten plastic into a mold, where it cools and solidifies in three phases: filling, packing, and cooling. The popularity of this process is evident from the numerous products produced using this method [3], which offers advantages such as high production rates, repeatability, and the ability to produce complex shapes with tight tolerances using a variety of plastic materials.

The passage emphasizes the increasing importance of semi-artificializing shuttlecocks for environmental protection. Synthetic shuttlecocks offer better durability than feathered ones, albeit with more complex aerodynamics, resulting in slower movement but better speed retention [4]. Feathered shuttlecocks are made using feathers from the left wings of ducks or geese [5], which raises sustainability concerns. The shift towards semi-artificial shuttlecocks represents a positive step in addressing environmental issues while maintaining the game's essential characteristics. Previously, the production of shuttlecocks required a large amount of duck feathers and rubber, resulting in unnecessary waste and environmental pollution. Improvements in the artificialization of shuttlecock production have significantly reduced this waste. Manufacturers now use friendly materials to produce shuttlecocks, increasing product sustainability and protecting the environment. Furthermore, this provides athletes with a better playing experience.

2. 3D MODEL FOR FEATHER RIBS OF SHUTTLECOCK



a) 2D drawing



b) 3D model

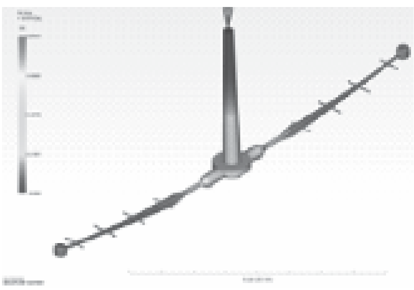
Fig. 1. Detail drawing of the product

The detailed drawing of the product is shown in Fig.1, and the feather ribs must meet the requirements for strength, weight, and flexibility. Therefore, a technical plastic material with low shrinkage coefficient was chosen. Among the available materials, Polyamide 6 with shrinkage coefficient of 1.0 is a suitable material for making the shuttlecock body. The product specifications are indicated on the drawing.

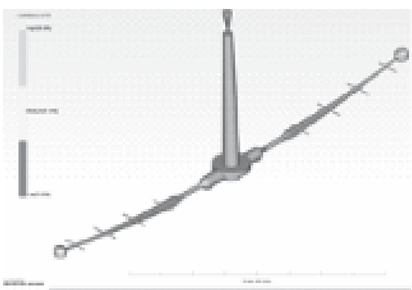
3. METHODOLOGY

Simulation of processes:

In this study, the finite element method and boundary element method embedded in Moldflow were used to identify potential defects. Then, the process parameters are established to design and manufacture the injection molding. Based on the aforementioned properties, PA resins, specifically PA6, are suitable for the product's operational requirements.



a) Fill time

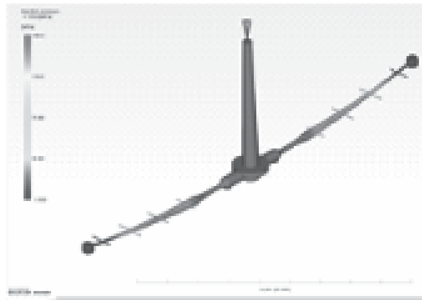


b) Confidence fill

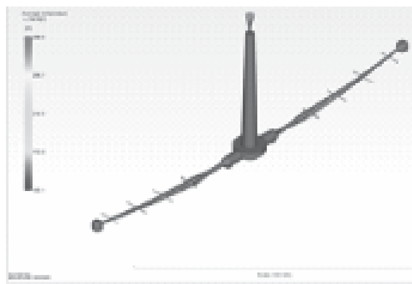
Fig. 2. Fill time and confidence of fill

The filling ability is 100% and there are no defects. Time fill time is approximately 0.87s. The simulation result is shown in Fig. 2.

Fig. 3 illustrated the average temperature and pressure during injection process. The average temperature of the molding process is 298°C. The injection pressure is approximate 159 Mpa.



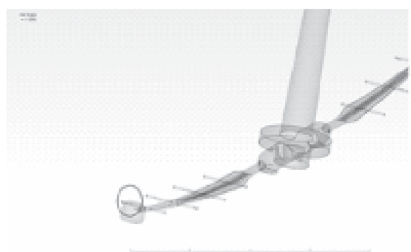
a) Injection pressure



b) Average temperature

Fig. 3. Injection pressure and average temperature

The locations of the weld line and air traps were determined in Fig.4. It is the basis parameter for mold design and prediction of possible damage during injection molding.



a) Air traps

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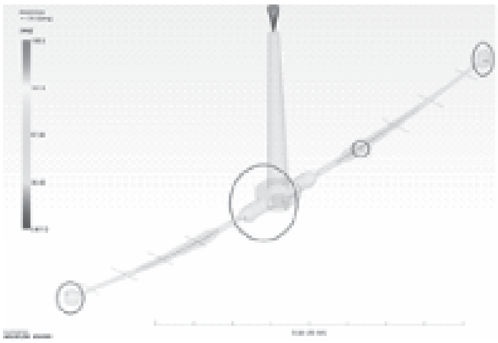

b) Weld line

Fig. 4. Air traps and weld lines

Design of the sliding system:

In this case, core was pulling with angled ejection, and undercut release, a cylindrical cam can be designed to control these actions synchronously.

Calculations for the slider cylindrical cam, where:

Length of the cam's angled section (L_a), length of the cam's straight section. (L□), sliding movement distance (M), cam's tilt angle (α), gap between the cam and the sliding plate (C), cam's dwell distance (D), blocking distance for movement (d), length of the straight edge of the hole (e).

$$M = L_a \times \tan\alpha - C \quad (1)$$

$$D = (Ls - e) + \frac{C}{\tan\alpha} \quad (2)$$

From equations (1) and (2), it follows that:

$$L_a = \frac{M + C}{\tan\alpha} \quad (3)$$

$$Ls = \frac{D \times \tan\alpha - C}{\tan\alpha} + e \quad (4)$$

Heat Exchanger:

- Mold dimensions: 230 × 200 × 163 mm;
- Mold material: SKD 61 Steel;
- Ambient temperature: 30°C;
- Mold temperature: 100°C;
- Time required to reach temperature: 20 minutes.

To calculate the heating power needed for the mold, consider the entire block with the surface areas mentioned. The heat required for the mold includes the heat needed to raise the mold temperature and the heat loss due to thermal exchange with the surrounding environment.

Heat required to raise the mold temperature from 30°C to 100°C:

$$Q_{gn} = G \times c_p \times \Delta t \quad (5)$$

With: $G = 58.48$ kg; $c_p = 0.45$ kJ/Kg52; $\Delta t = 100 - 30 = 70$°C.

Thus:

$$Q_{gn} = 58.48 \times 0.45 \times 70 = 1842.12 \text{ kJ}$$

The molding machine operates in a stable temperature environment. The mold temperature is transferred to the outside environment naturally. Therefore, we calculate heat loss to the environment as natural convection.

The heat loss is the total heat transferred through the environment at the 6 faces of the mold.

Heat loss calculation:

$$Q = a \times S \times \Delta t \quad (6)$$

Grashof number (Gr):

$$Gr = \frac{g \times \beta \times t \times L^3}{v} \quad (7)$$

Refer to the physical property tables for dry air: $v = 16.69 \times 10^{-6}$

With $g = 9.81\ m/s^2$.

$$\beta = \frac{1}{t + 273}$$

$$\Delta t = 100 - 30 = 70°C$$

Horizontal surface: L = 200 (select smaller dimension):

$$Gr_n = \frac{9.81 \times \frac{1}{338} \times 70 \times 0.2^3}{16.69 \times 10^{-6}} = 973.832$$

Vertical surface: L = 163 (select taller dimension):

$$Gr_đ = \frac{9.81 \times \frac{1}{338} \times 70 \times 0.163^3}{16.69 \times 10^{-6}} = 527.177$$

Rayleigh number (Ra):

$$Ra = Gr \times Pr \quad (8)$$

Refer to the tables for dry air: Pr = 0.699
Thus,

$Ra_n = 973.832 \times 0.699 = 680.708$
$Ra_d = 532.177 \times 0.699 = 368.497$

Heat transfer coefficient:

$$\alpha = \frac{Nu \times \lambda}{L} \quad (9)$$

Refer to the tables for dry air:

$$\lambda = 2.76 \times 10^{-2} \frac{W}{m} \text{degree}$$

And the coefficient:

$$Nu = C \times Ra^n \quad (10)$$

Heat Dissipation from the Surfaces:

$Q_1 = a_{nt} \times S \times \Delta t = 0.8630$
$Q_2 = a_{nd} \times S \times \Delta t = 1.5875$
$Q_3 = a_d \times S \times \Delta t = 1.2368$
$Q_4 = a_d \times S \times \Delta t = 1.4224$

Total heat loss:

$Q_{tt} = \sum Q = 0.8630 + 1.5875 + 1.2368 + 1.4224 = 5.1097$ kJ

Total heat required:

$Q = Q_{gn} + Q_{tt} = 1847.23$ kJ

Select the Heating Time for the Mold: 20 minutes.

Required Heating Power:

$$P = \frac{Q}{t} = \frac{1847,23}{1200} = 1.539\ kW \quad (11)$$

We select a heating element with a power of 1.6 kW.

4. RESULTS AND DISCUSSION

The completed 2D drawing and 3D model of the injection molding for feather ribs is shown in Fig. 5.

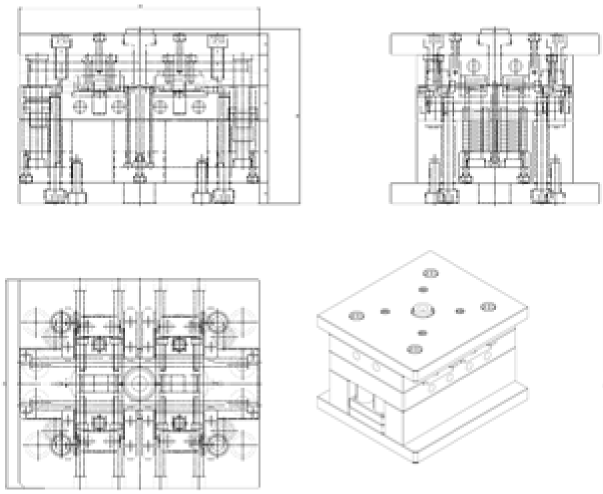

Fig. 5. 2D drawing of the mold

5. CONCLUSION

In this article, a detailed analysis of the plastic injection molded shuttlecock feather ribs product, including both description and results of the testing process is presented. Moreover, some basic characteristics of the injection mold design are introduced to provide a comprehensive overview of the production process for this product.❖

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